Gemini
Mount
Control
System
Report

MCS Critical Design Review Report

Gemini

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This report describes the minutes of the MCS CDR.

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1. INTRODUCTION

The Gemini MCS CDR was held on Tuesday 10th December 1996. The following people were present:

J. Wilkes (RGO)
C. Carter (RGO)
A. Foster (RGO)
M. Stewart (ROE)
M. Warner (GPO)
C. Mayer (RGO)
M. Fisher (RGO)
A. Rudeen (IGPO)
M. Hunten (IGPO)

The following people acted as virtual reviewers and submitted comments via e-mail:

M. Ravensburgen (VLT)
J. Maclean (RGO)
T. Coleman (ANL)

Note that Tom Coleman's comments arrived after the review so were not discussed at the meeting. His comments have been addressed by the MCS team. Thanks to everyone who has taken time to review our documents, all comments have been gratefully received.

The main body of this report describes the issues raised by real and virtual reviewers. Each paragraph will fall into one of the following categories :

1. Immediate action (marked by the ▼ symbol). This indicates an action that needs to be immediately resolved before CDR report is issued, this will usually mean a change to the CDR documentation.
2. A comment (marked by the **C** symbol). This indicates that no a specific action is needed.
3. Action (marked with a name in **bold type**). These require action to be taken by the person(s) specified. Each of these actions is uniquely numbered - the number is shown in brackets after the relevant person(s) name. Note that a number of actions are specified as **Action on GIS**. These actions are the responsibility of whoever takes over the GIS workpackage - presently unknown.

2. THE ISSUES

The issues raised by the review are subdivided into comments on each of the review documents.

2.1 General Comments

There does not seem to be a ‘grounding scheme’ for the electronics. This helps also during the early design stage in order to define points where a galvanic isolation has to be made. Do not try to implement ‘single point grounding’ for this big machine.

> **C** - The grounding scheme for the drive cabinets and devices (motors/amps/tachos) is shown in the schematic drawings in section 3.1.3.3.2, specifically figure 3.5. This is based upon the working friction drive test rig configuration. Unfortunately the FST-2 amplifiers seem to be rather sensitive to the way there are earthed, particularly the tacho inputs. Given this, and the mystical nature of grounding problems, the drive system will be flexible in its configuration and we will be prepared to modify the planned scenario during the factory tests.

There does not seem to be a functional block diagrams for the design of the whole servo system for the mount. It might be that the MCS does not cover the whole servo, but ‘somewhere’, these block diagrams must exist.

> **C** - Figure 3.2 shows how all the various servo loops fit together from a functional point of view. This may seem simplistic, but attempting to include more details in a single diagram complicates the issue and makes the diagram unreadable. The details are included in the relevant parts of the rest of the documentation.

There does not seem to be a block diagram for the electronics, starting from VME and including all hardware of the MCS.

> **C** - I am not sure of the usefulness of such a diagram, given that most of the electronics are VME cards from the Gemini standard controller range. However, I shall endeavour to put together such a diagram to serve as a road map to the MCS electronics.
>
> **John Wilkes (1)** - Produce a diagram that details all the electronics used by the MCS.

2.2 Comments on CSDD

Section 2.4. Hardware Requirements. PMAC3 requirements listed here are not consistent with those of Counterweights and Service Wraps PMAC Set Up: PMAC Options and Accessories. The requirements listed in the latter document are recommended, in particular, the DPRAM and 60MHz processor.

> **C** - We have specified DPRAM and 60 MHz processor for all three PMAC cards. This is reflected in Table 2.1 in section 2.4.

Section 3.1.1. Although not strictly relevant for this review, what is the status of the Cassegrain Rotator WP?

> **C** - MCS WP to take on S/W after delivery of MCS. Subcontractor will do hardware (IGPO in control).

Section 3.1.2. How is the servo system going to implement the reduction of torque in the event of drive slippage? This has been seen on the test rig (see 3.1.3.4.2) but is it expected to be present on the mount itself.

> **C** - The reduction of torque requirement is meant to apply when the drive wheels are slipping uncontrollably (wheel spinning) due to some fault situation. This will be achieved by monitoring tacho and encoder signals in the software. The low level of slippage that has been observed on the test rig does not warrant a removal of torque, though a method of preventing this would be welcome.
>
> ▼ - Add this statement to CSDD.

Section 3.1.3.3.1. What is the effect of missing updates to the motion buffer by the EPICS system? What precautions are being taken to ensure this doesn't happen?

> **C** - The 100 Hz scan task in the MCS will keep the move argument buffer replenished if the TCS stream is interrupted by ethernet delays. If the 100 Hz task gets locked out by a problem internal to the database, then the affect would be that the mount would move back to a position it occupied 100 milliseconds ago and retrace it's path over the next 100 milliseconds and so on.

Section 3.1.3.3.1. The time synchronisation indicates an additional jitter of up to 1ms. This is presumably only a problem on first initialising the motion buffer. It does not affect every 5ms update of the buffer by the EPICS system?

> **C** - This will only be a problem when the motion program is started. Starting the motion program will only occur when the MCS receives a FOLLOW command. The stream of continuous 20 Hz data after that will not be affected. The delay of up to 1 ms will be constant for the track (i.e. until the motion program is restarted). There will effectively be a offset between real time and the track time. This is not expected to be significant, if it is, the auto-guider/tip-tilt system should easily remove it.

Section 3.1.3.3.2. What is the reason for allowing the GIS to supply a velocity demand to the mount axes? Is there any feedback to the MCS to let it know when this is happening to prevent the two potentially fighting against each other? or will this only be used when the mount has gone into a hard limit.

> **C** - There is a requirement that the GIS should be able to move the telescope in the absence of the MCS. In order to keep this as simple as possible, the tacho loop is closed in the power amps so that the GIS can demand velocity (demanding torque will require the GIS to close a servo loop). To stop potential fighting, the GIS must demand zero velocity while the MCS is enabled (drive condition signal asserted) and the MCS must demand zero velocity while the MCS is disabled (drive condition signal dis-asserted).

Section 3.1.3.3.2. What is the effect of removing a motor from the drive?

> **C** - The tacho loop gain and the maximum attainable torque is reduced by 7/8 (3/4 on elevation). The change in tacho gain can be compensated for by re-programming the FST-2's, so as long as the reduced maximum torque can still drive the telescope, there should be no change in drive performance.
>
> **Action on GIS, Andy Rudeen and John Wilkes (2)** - Decide upon a way in which individual amplifiers can be selectably enabled. In this way, certain motor drives can be disabled. This will probably be a GIS function.

Section 3.1.3.3.2. FST-2 connection diagram: there are no existing plans to use the Amplifier "Motor Over Temp" input (to an external temp sensor). This type of safety mechanism will be implemented using standard thermal (current sensing) discrete motor overload relays which hard-wire to cut Drive input power when tripped. These relays can be equipped with auxiliary contacts for computer (GIS) sensing also.

> **Mark Warner & Andy Rudeen (3)** to investigate whether temperature sensors can be mounted on the drive motors.

Section 3.1.3.3.2. Drive Configuration. Are the power amplifiers configured by command and, if so, do they retain their settings.

> **C** - Yes. The FST-2's are configured using an RS232 link. These are saved into non-volatile memory so configuration is preserved after a power cycle.

Section 3.1.3.4.2. Test Rig. At what percentage of the theoretical value do the friction wheels slip? Is there a proportional effect at all? Was the theoretical limit modified to account for increased loading effects due to misalignment of the surfaces? How does the slip manifest itself? Does it correspond to the hysteresis effects known to occur with friction driven encoders?

> **John Wilkes & Mark Warner (4)** - Further friction drive tests will address all these questions and more.

Section 3.1.3.4.2. Test Rig. How are the drive rollers to be aligned on the actual telescope and are there implications for the MCS in either the alignment process or in test and maintenance procedures?

> **C** - The alignment should not effect the operation of the MCS.

Section 3.1.3.4.2. Effective gear ratio mismatch. It is the very high circumferential stiffness that enables drive motors to share torque mismatches without 'low frequency' dynamics to worry about. In this sense the test rig does not reproduce the elevation axis drives. I guess the first torsional mode of the elevation axis is quite high frequency?

> **C** - The worry here is that if a differential torque exists between the two elevation drive assemblies, this will wind up the effective spring that is formed from the compliance of the drive disks and the centre section. One effect of this would be to impose an oscillation upon the tracking error. We will keep an eye out for this during the factory tests.

Section 3.1.3.4.2. If mis-matches in tacho loop parameters occur at the telescopes what diagnostics are available in the MCS to monitor this to prevent one motor doing most of the work.

> **C** - Small mismatches in each tacho loop are expected, which means that the motors will do unequal amounts of work. However, the differences should be small. The MCS monitors motor currents, so large imbalances (i.e. fault conditions) can be detected.

Section 3.1.3.4.2. Does this slip occur even at very low speeds and is this expected to be a problem with the real mount axes?

> **C** - This work really isn't complete, we think slip will occur at very low speeds, but we don't think it will be a problem with tracking. The slip is small and only seems to occurs at change of direction. Note that slipping drive wheels do not have an effect on the encoder output, so position information is not violated.

Section 3.1.3.4.3. Test Objectives. To what extent will the mounting arrangement at the factory modify the expected frequency response, particularly the elevation nodding mode?

> **C** - The dynamics of the factory set-up will be somewhat different to the real telescope for a number of reasons: The dummy primary mirror cell is 10-15 times too light, the dummy secondary is slightly light and there will be no pier dynamics. This should not detract from the usefulness of

the factory tests, although final tuning parameters for the telescope cannot be obtained and re-tuning will have to take place on the mountain.

Mark Warner & Mark Sheehan (5) - Is the lowest resonance of the elevation axis present in the factory set up?

Section 3.1.3.4.3. Is the schedule for shipping the drive cabinets to Telas on course (The MCS IOC's are used in the development of the TCS)?

C - Yes the schedule is still correct. A MVME167 CPU card will not be needed during the factory tests, so both the MCS cards can be left behind in Cambridge. We will need to take a VME crate however.

Section 3.2.2. How are the look up tables that supply the encoder corrections going to be up/down loaded? Is this an engineering interface command?

C - This requirement will be met by the software. All look-up tables will be loaded at iocInit time, either using 'lut' records or 'genSub' records (if 'luts' do not provide the required number of outputs). The downloading of tape encoder compensation parameters to PMAC will be done from a 1 Hz scan task which will only be enabled during tracking, i.e. not during a PMAC jog command.

Section 3.2.2. Encoder Subsystem Purpose. Will facilities be available to log encoder combinations against the current virtual encoder output used to servo the telescope? For example could one servo on the average of one pair of tape heads and log the other pair or both pairs?

C - No. The only VE combination that can be logged is the current output. However, it will be possible to log all of the inputs to the virtual encoder, so any given VE combination can be calculated off line. We feel that it would be too much of an overhead to calculate all possible VE combinations in the DSP code, simply for logging purposes. Remember that this code has to execute in very much less than half a milli-second.

Section 3.2.3.2.1. Doesn't the Heidenhain tape system offer a "Z" or reference channel of distance-coded marks which could more efficiently take the place of the 94 discrete electromagnetic fiducial switches and their associated interface circuitry? One would be required to move just a short distance to pass over 2 sets of reference marks which are uniquely distanced. A software algorithm/look-up table is then all that is needed to ascertain absolute location.

C - Absolutely right - the Heidenhain tape head does have an additional 'reference mark' output which we have not yet used, and which could be used as you describe. However, the general feeling is that this system should be seen as an addition to, and not a replacement for, the magneswitch fiducial system. Some (if not all) of the fiducial switches should be retained (if only around the limits to provide a hard limit signal to PMAC), at least until the Heidenhain reference system is investigated further. Also, see next comment.

John Wilkes & Chris Carter (6) - Investigate the Heidenhain distance coded reference system and how it can be interfaced to PMAC.

Section 3.2.3.2.1. Fiducial Encoding System. Is use being made of the Heidenhain absolute position reference marks and how does this impact on the fiducial system? Clearly fiducial switches should be retained since they reference the structure whereas the tape only references itself. However, reference marks of any type are subject to any non-rotational effects and may produce a scatter of values.

C - See previous comment and action. The fiducial switches will allow detection of any movement in the Heidenhain tape.

Section 3.2.3.2.1. Where will the fiducial encoding circuits be mounted? How big will the boxes be? What are the power supply requirements and where does the power supply come from?

> **C** - Current proposals have the fiducial electronics boxes mounted in two locations. The elevation fiducial electronics will be mounted on the elevation disc. The azimuth electronics will be mounted on the pier at a suitable location TBD.
>
> Case sizes are TBD (largely because the fiducial requirements are under revision due to the choice of tape encoder). As each individual fiducial requires one associated detector module PD-100 (approx. $70 \times 40 \times 30$mm) casing is heavily dependent on number of fiducials. There are tight size constraints in the elevation case however. Mark Warner has pointed out that a working maximum for the elevation case size should be $300 \times 450 \times 85$mm (external). This is too small to contain the specified provision of 22 elevation fiducials.
>
> In azimuth the situation has no such restriction. My proposal is for a 6U KM6-II Universal Subrack Kit (RS 500-421) to house the 72 fiducials and associated equipment. This should be housed in a cabinet (see *Schroff* range) and can be placed at a suitable location in the under-mount area. Cooling fans etc. can be provided as required.
>
> Estimates of power consumption for the specified number of fiducials is:
>
> > Azimuth: 17W
> > Elevation: 7W
>
> Both units require a single +12VDC supply (+5V for the encoding logic is derived).
>
> For the azimuth case a switched-mode power supply integral to the 6U subrack can supply DC from a local 120VAC source on the pier. Elevation should have DC supplied across the cable wrap from a local power supply (in a drive cabinet?)
>
> Clearly this situation cannot be satisfactorily decided until the number of fiducials is finalised.

Section 3.2.3.3.1. Why is it that the encoder system assumes an absolute position of zero on booting? In elevation this will generally be an illegal value would it not be better to assume 15 if the tilt switch indicated it was less than 45 or 90 if the tilt switch indicated greater than 45? Something similar could be done using the topple bracket positions in azimuth.

> **C** - Good point. The reason the encoder system assumes position zero is because that’s what all the PMAC counters and registers are initialised to. This is fine for azimuth but, as you point out, will mean the elevation axis initialises in a soft limit. PMAC can be programmed to initialise it’s motor position register to some value other than zero, I think the best solution is to set this to 45 degrees. I don’t think it is sensible to read topple brackets and the tilt switch since the PMAC card does not have access to these, so the software would be unnecessarily involved in encoder initialisation.
>
> ▼ - Change initial value of virtual encoder to 45° for elevation in CSDD and Main Axis PMAC Set-Up document.

Section 3.2.3.3.1. Can the absolute encoder on the azimuth wrap be read by the start-up initialisation?

> **C** - No. The azimuth absolute encoder is read by the GIS only.

Section 3.2.3.3.3. Fiducial Passed. If the fiducial encoder system does not latch a hardware counter but sets a flag to be dealt with in the virtual encoder routine, what is the expected error due to the delay between actual detection and storing of the VE_OUT value? Presumably it is this that fixes the mount velocity when performing a datum operation but when the azimuth axis rate is high is there any point in recording fiducial information?

> **C** - The maximum delay in detecting a fiducial passed signal will be one servo cycle (currently 0.5 ms) and yes this will set the velocity while performing a datum (tests on the encoder test rig have shown 2 mm/s is slow enough). In operation at high velocities, there is likely to be a significant

error in the fiducial passed signal. However, given velocity, the maximum value of this error can be calculated, so the information is still useful.

Section 3.2.3.3.3. Figure 3.21. Elevation combining algorithms. The elevation translation sensor readings should be heavily averaged or filtered before combining them with the other encoders unless they are inherently noise free devices.

Mark Warner, John Wilkes, Andy Rudeen (7) - Select suitable devices for elevation translation sensing.

Section 3.3.2. Interlock interface subsystem. As this subsystem supplies the drive enable signal to the GIS does this mean that the MCS has to be running in order to move the telescope via the manual handset or is this catered for in the design of the interlock system?

C - No. It seems that the name ‘Drive Enable’ has confused some people. This signal is simply part of the interface between the MCS and the GIS. It is NOT the FST-2 ‘/Enable’ line, only the GIS has control of the FST-2 amplifier signals. The GIS can do whatever it likes in the absence of the MCS since it calls all the shots (controls the power to the drives and the brakes and controls the amplifier enable lines). The purpose of the description in section 3.3 is to outline how the MCS *wishes* the GIS to operate during MCS control.

Section 3.3.3.1. What is the reason for the MCS not querying the interlock system via Channel Access to find out why it has been interlocked?

C - Given the distributed nature of EPICS, it seems crazy that the MCS should have to interrogate the GIS database for information that it simply passes on to the TCS. The MCS has no use for this information. However, this is simply a philosophical issue and there is no reason why the MCS cannot query the interlock system via Channel Access to find out why a drive has been interlocked.

Andy Foster (8) - Add requirement to MCS SDD for the MCS to read the GIS upon unexpected interlock condition, to provide information about the reason for the interlock to higher systems.

Section 3.3.3.1. The MCS is also required to respond to a global interlock event from the GIS.

Given the interface described in our documentation I don’t believe that a Global Interlock event is necessary, I suggest that if anybody disagrees with this then they do not understand the philosophy of the design as it stands. Further, until the design of the GIS is formally advanced I don’t see how such a requirement can be justified, or the need for anyone else to accept it.

Action on GIS (9) - Existence of a Global interlock event to be justified. If it is, the required action from the subsystems should be defined.

Section 3.3.3.2. GIS Functionality. Why remove the brakes before the AMP OK signal? How long does it take for the AMP OK signal to be asserted? What happens if it doesn’t get asserted and the T/S balance is not perfect?

C - It takes approximately 0.25 seconds for the brakes to release.

C - It is not the place of the MCS to wholly define GIS functionality. To repeat: the purpose of the description in section 3.3 is to outline how the MCS *wishes* the GIS to operate during MCS control. It is suggested that the GIS design should include a table of possible start up conditions/faults.

▼ - Change the order of removing brakes and enabling amplifiers.

Action On GIS (10) - Include a table of possible start-up conditions within the GIS documentation.

Section 3.3.3.3.1. Limit switches. One reason why the telescope is approaching a limit is that an encoder has failed in some way or a datum has not been carried out in which case having virtual limit switches triggered by mount position is not much use. Unless there are other checks in place to prevent such a common fault leading to the triggering of the GIS limit, which is considered undesirable, then there should be physical pre-limit switches.

C - No move commands (except low level PMAC commands) will be allowed before a datum command has been successfully issued. Hopefully encoder failure will not be a ‘common fault’. Given these two facts the GIS limit should not be activated as frequently as implied. For extra safety in elevation, fiducial switches could be used to provide a hard limit signal to PMAC. This would not work for azimuth because of the positional ambiguity.

Chris Carter (11) - Look at modifying fiducial encoding circuits to provide additional open collector outputs from the elevation fiducials nearest the limits.

Section 3.3.3.3.1. Is there a switch on the hard stop (used to drop out the motor drive contactor)?

C - No. Note that hitting the GIS limit (S2 in the document) will result in the drive power being cut. The GIS should only re-power if a demand to move in the direction out of the limit is received.

Mark Warner (12) - Can such a switch can be fitted?

Action on GIS (13) - Is such a switch necessary?

Section 3.3.3.3.1. Is the GIS switch activated the whole time the axis is past the limit?

C - Yes.

Section 3.3.3.3.1. Interlock System Limit. Why you think an area of reduced velocity within 5° of the stop is not a good idea. The interlock stop is a brute force method, to be avoided, not much different from hitting the hard stop.

C - Agreed that the interlock stop is to avoided if at all possible. When in MCS control, the software implements a dynamic velocity limit around the end stops designed to stop the axis completely before the GIS limit is reached.

Action on GIS (14) - Is a pre-limit switch required for GIS hand-paddle operation?

Section 3.3.3.3.2. Azimuth Axis Special Functionality - Topple brackets. To my knowledge, topple bracket failure has occurred three times on the WHT, twice through physical damage due to misalignment of the mechanism (probably by clumsy feet) and once by deliberate interference. If the geared azimuth encoder is not considered robust enough to give adequate fail-safe protection then a tamper-proof geared limit switch arrangement can be considered.

C - The topple brackets are substantial pieces of metal with powerful spring mechanisms. One man could just about move a bracket, so tampering would have to be very deliberate.

Despite this, no matter how difficult the topple brackets are to move, the fact that it is possible means that extra precautions have to be taken. It is true that the absolute encoder cannot be considered totally fail-safe, however, given the likelihood of a topple bracket misnomer *and* an absolute encoder fault, we think that this is sufficient precaution.

Action on GIS (15) - Regular operation tests (independent of the topple brackets) should be carried out on the absolute encoder.

Section 3.3.3.3.2. Note that there are two striker brackets and two damper units for each end of elevation travel (one on either side of the OSS). For horizon maintenance access position (lower than 15°), both lower striker brackets have to be rotated and pinned out of the way.

Action on GIS (16) - Are two sets of GIS limit switches needed at each end of elevation travel?

Section 3.3.3.3.2. Note that there should be an additional pair of azimuth limit switches positioned at the azimuth safe range while in elevation 0-15° access position. These switches should be activated the whole time that that azimuth axis is not in the safe range.

Mark Warner (17) - Define safe ranges for azimuth during elevation 0-15° access position.

Section 3.3.3.3.2. What happens if the elevation striker brackets are rotated back into position after passing the 15° limit?

C - This cannot happen due to the mechanical design. Once the elevation axis is below 15°, the striker brackets are physically obstructed (by the damper units) from returning to their normal position.

Section 3.4.3. MCS OVP. The circuit could be modified to provide digital outputs instead of analogue by adding two comparators. This would make interfacing to the GIS PLC easier, since we do not care how fast the axis is going, just if it is going too fast. Also, the GIS PLC has no ±15VDC (or any power for the outside world, digital or analogue).

C - There is no problem with providing digital outputs rather than analogue ones - this would also be easier to fail-safe. However, it is less flexible since the maximum velocity is now fixed in hardware, though this may also be desirable.

I still find it hard to believe that the Allen Bradley PLC system can not be configured to supply ± 15V. If this is true, the supply for the VCC and TAV circuits can be used. However, since the GIS is receiving the signals, the proper place for this supply to come from is the GIS.

▼ - Update chapter to reflect digital outputs from over velocity protection hardware.

Chris Carter (18) - Modify over velocity protection circuitry to provide digital outputs rather than analogue ones.

Section 3.4.3. Protection Hardware Function. The tacho signals should be heavily filtered since commutation noise usually greatly exceeds ‘noise’ and amplification alone would not improve signal/noise much.

Chris Carter (19) - Add filtering and differential inputs to over velocity protection circuitry.

Section 3.5.3. Counterweight Subsystem Function. If there is a high coulomb friction level it may only be possible to approximately position the drive. Does the PMAC allow for this?

C - The PMAC ‘In Position’ range can be set by the user. Note that resolution of the encoder is ≈0.25 mm. We expect to be able to position the counterweights to this accuracy quite easily. An estimated accuracy of 1 mm is required by the application.

Section 3.5.3. Counterweight Drive system: Figure 3.27. Perhaps a “centre-of-travel” fiducial or two would expedite initial set-up/calibration of the motor absolute encoder relative to the load position. Will the telescope balancing be integrated in any manner with the MCS controls or will it be a separate manual process (this question may be outside the scope of the MCS Work package)? What kind of low-level diagnostics can be provided to assure the integrity of the load position with respect to the encoded motor position?

C - There does not seem to be any point of including fiducial switches that will only ever be used once. Defining the absolute encoder is not seen as a problem.

C - Currently balancing is a separate manual process carried out through the MCS engineering screens.

C - Only a fault condition would cause an error between load position and encoded motor position. An imbalance in the main axis drive currents would show up such an error.

Section 3.6.1. Note that the mechanical design of the cable wraps is not covered in reference [3]. Gordon Pentland is the designer and should be able to provide the relevant reference.

▼ - Add cable wrap mechanical design reference.

Section 3.6.2. Motor drive current from cable wrap motors - how is this going to be used by the MCS?

C - This has always been a requirement on the MCS. I suppose the signals can be used to detect a possible cable jam.

Section 3.6.2. Service Wrap-ups Subsystem Purpose. What happens if a wrap fails to drive or drives in the opposite direction? Does the differential torque put undue loading on the wraps? If a hardware limit activates the GIS which stops the axis what is the recovery procedure? The presence of physical stops which allow for the telescope to drag the wrap with it means that the wrap servo and the telescope servo could fight each other in a fault condition, is this OK?

▼ - Include a table of possible fault conditions in CSDD. See next comment.

Section 3.6.2. GIS and the service wraps - why do you think that losing the service wrap is not a safety issue? We have a definition of major damage that this would fit under (excised from a "Technical Note on Safety Systems", R.J.McGonegal):

- Major Injury - any injury that results in admission to a hospital, such as bone fracture, second- or third-degree burns, severe lacerations, internal injury, chemical or physical agent toxic exposure, or unconsciousness.
- Major Damage - breakage of either M1 or M2 as well as any damage which requires the observatory to go off line for more than 1 day.

C - A decision was made pre-PDR that there is no need to protect service wrap and counterweight systems with the GIS. It was decided that the protection features built in to the MCS were sufficient given the level of safety required. A problem arises when the GIS wants to move the telescope when the MCS, or more particularly the wrap servos, are not present. In this case the axis must drag the wrap and the signals from the micro-switches must be ignored. This is a GIS issue, not a MCS one.

Action on GIS (20) - Define effects of wrap limits in GIS axis control modes.

Section 3.6.3. Cable wrap drive configurations. The current mechanical design uses two elevation axis cable wraps and drive assemblies, one on each side of the telescope. This was finalised just a few months ago. Both elevation drives use their own LVDT for position sensing. Has MCS interface hardware been allocated for two elevation service wraps?

C - Yes.

Section 3.6.3. Cable wrap drive configurations. The TBEG (Gordon Pentland) has made mechanical provisions for mounting a second servo motor to assist in driving the azimuth axis cable wrap mechanism if needed. This will not be used unless it is determined to be needed after on-site assembly and testing. The MCS hardware should allocate appropriate “spare” I/O for this possibility (analogue demand signal out to this motor, analogue input for motor current). Only 1 LVDT for differential position sensing will be used in any scenario (1 or 2 drive motors).

C - This is a slight change in requirement. There are two ways to do it:

- Fan out the motor demand from PMAC to both motor amplifiers. This is the easy solution, but will only work if both motors should receive the same signal.
- Use the spare DAC channel on the C&S PMAC card to control the second motor. This method can be used if the two motors require different demands (e.g. the case of bias to remove backlash).

▼ - Add appropriate comment to CSDD.

Andy Rudeen & Gordon Pentland (21) - Decide which connection scenario and hence how many more inputs and outputs are required.

Section 3.6.3. Outputs from LVDTs. The outputs from the selected LVDTs are nominally ±10 VDC, not ±5 VDC. This is produced by the selected LVDT electronic conditioning module, a Lucas-Schaevitz #LVM-110-DC.

C - If the signal is differential, the input range to PMAC ACC28 is ±5V. So we either use a single ended signal, or physically divide the signal by two. Remember that the wraps are regulators rather than servos so, as long as the max. error is less than 5V, we could ignore the range difference. We may want to check that the ACC28's are protected against over voltage just in case.

John Wilkes (22) - Check input protection on ACC28's.

Andy Rudeen (23) - Check to see whether the LVM-110-DC can supply ±5V differential.

Section 3.6.3. Cable Wrap servo motor configuration - the Cable wrap servo motors (brush-type DC servo motors) were ordered without the incremental encoder option which is shown in table 3.12. Differential position sensing is done via the LVDTs.

▼ - CSDD should be updated to reflect this.

Section 3.7.1.1. Note that the translation sensors used to provide corrections to the main elevation encoder are read directly by PMAC, not through the monitoring subsystem.

▼ - Add comment to CSDD.

Section 3.7.3. Figure 3.32. Nodes C and D may be more useful under the mount base rather than on top of it.

Chris Carter (24) - Look at most useful location for mount base node boxes.

Section 3.7.3.1.3. If sensors could rely on being able to get power from the node box, it could simplify the wiring and services needed for every sensor. There is no reason that there should not be a limit on this amount. Most sensors have very low power consumption.

C - Although we understand these points, we are opposed to providing power from the node for the following reasons:

- We would like to keep the power dissipation within the node box as low as possible; bear in mind that the node box is not actively cooled, and is sealed.
- It may be a problem obtaining and finding space in the node box for a larger power supply module (remember that substantial de-rating is also required, especially in the absence of forced cooling).
- Providing external power will involve adding additional protection circuitry (fuses/regulators/filters) to an already crowded board. We are already pushing the space limits - unless we move to a larger box.

- We could have an external power source included in the breakout box, however. This could easily power sensors, and would be separate to the node circuitry.

Chris Carter (25) - Look at including a separate power supply as part of the breakout box.

Section 3.7.3.4.5. How will the monitoring nodes be set-up?

C - An engineering screen will be provided to set up the inputs to each node.

Section 3.7.3.4.7. CAN data rate. If possible, you should run the CANbus at 250 kbps. This not only makes the bus more reliable (as is said in the document), but also gives commonality with the PCS buses. This would make life easier for the maintenance staff who will then have only one set up for the bus analyser etc.

C - Agreed. At 250 kbps we will meet the original 1Hz requirement easily. Higher rates could be implemented in future if the need is there.

Section 3.7.3.4.6. CAN bus message/data format. Whilst your set-up and configuration messages give some neat functionality you are putting additional complexity into the node box code. I would suggest that you just go for the option, described in the document, where the VME system polls the node for data as required. This will slightly reduce the volume of data you can return, but for this subsystem which is monitoring slowly changing signals, this should not be a problem. If this is done you will (probably) be returning all the input signals. The VME only has to look at the values it needs and can discard the rest. e.g. there doesn't seem to be much point in disabling individual binary inputs at the node box when it is returning all the bits anyway. The node CPU should be able to cope with all the processing you need, so you may as well let it and just pick out the data you want. The rate at which you read the data across the CAN bus can be determined by the scan rate of the relevant EPICS input record which can be changed quite easily and dynamically if required.

C - In the first instance, the VME system will poll each node for data at a fixed rate; this will reduce the node software complexity but increase bus traffic overhead. EPICS must poll each node at some fixed rate, determined by the sample decimation of the node box. The anti-aliasing filter is unaffected, as the initial sampling is always performed at one fixed frequency before decimation. We recommend keeping the options open on increasing the node box code complexity as described in the document. It may enable valuable features to be more easily implemented later.

Section 4.2.2. Table 4.2. Is the range for the azimuth and elevation position error records correct?

C - It should probably be ±550° to take in to account the area outside the observing limits. This also applies to the current position records.

▼ - Update table to reflect correct ranges.

Section 4.2.2. Table 4.4. Records are required to monitor counterweight drive current.

C - There is no requirement to monitor counterweight drive current.

Section 4.2.2. Table 4.5. A fourth “SW Motor Status” and “SW Drive Current” record should be added to accommodate the potential future usage of a second azimuth cable wrap axis drive motor.

C - Extra SW Motor Status is required only if the additional motor is to have its own servo channel (unnecessary and potentially a bad thing anyway).

▼ - Update table to include new records.

Section 5.1. Take it as a suggestion to make a full test of this interpolation s/w, INDEPENDENT from the integration schedule on the telescope. My experience is that these things need debugging, which is very time consuming (and normally not even scheduled).

C - Agreed. We intend to fully test the DSP code using our encoder test rig.

2.3 Comments on SDD

Section 2. Reference's Hardware installation should be replaced by ICD13 and genSub Manual should be replaced by GRRM. Does Ref. [18] (and others) have a document number?

C - The GRRM is out of date with respect to the 'genSub' record. The correct reference is the one given as this is up to date.

▼ - Find document numbers for all Gemini documents.

Bret Goodrich (26) - Update GRRM to include the genSub record.

Andy Foster (27) - Change reference to GRRM when updated.

Section 3.2.1. Do other TCS subsystems have similar requirements in terms of different modes of operation (Observing/Engineering/Mixed)?

C - No.

Section 3.2.1. Modes of Operation. Does mixed mode allow for a normal mode of observing but with ability to do things of a commissioning nature? I would expect this to be a major operating mode for the period leading up to full operation.

C - Yes.

Section 3.3. What is the significance of the titles of the subsections under "Module Decomposition"? Are they logical groupings only or do they have some other significance?

C - They are logical groupings. Hopefully the titles give some indication of the functionality provided.

Section 3.3.1. Are there not other engineering commands, e.g. to modify PMAC parameters, up/down load encoder compensation tables etc? Is WRAPINIT an engineering command?

C - Any valid PMAC command could be classed as an engineering command. However, as there are 73 pages of these commands in the PMAC manual, it would be pointless to list them here. We will provide an engineering screen interface to the PMAC cards in our system. These will allow communication with the mailbox registers on PMAC. Using this interface, any PMAC command can be issued. The downloading of encoder compensation parameters will be done continuously from a 1 Hz scan task which will be enabled when the telescope is tracking and disabled when it is slewing.

The WRAPINIT command is meant to be sent from the TCS or Engineering Screen.

Section 3.3.2. The "Gemini SAD will sample" - is this correct?

C - It is planned to put the MCS supplied SAD records on a 1 Hz scan, pulling in the values from this local area.

Section 3.3.3. Does MCS_Get_Data use pvLoad?

C - MCS_Get_Data will use "pvLoad", lut records and perhaps 'genSub' records, if lut records do not provide sufficient outputs.

Section 3.3.3. MCS_Get_Data. Will the counterweights move after a boot-up if a different setting is indicated in the lookup table or is a specific action required to allow the counterweights to move to the new telescope configuration?

> **C** - Nothing should move after an MCS re-boot. A CWMOVE command is required to move the counterweights.

Section 3.3.3. Currently the TCS does not have the information to send the MCS the instrument configuration. To do so requires the TCS to know which instrument is on every port. The only mechanism discussed so far to find this out is that as part of the instrument set-up an engineer will tell the instrument what port it is on and this will get written into a SIR record in the SAD e.g. sad:port1.VAL == "gmos", sad:port2.VAL == "hros" etc. Subsequently the TCS could read this information and send it on to the mount but the MCS might as well read this directly. This would have the advantage that balancing the telescope would not require the TCS to be running.

> **C** - Agreed. The MCS should read this information directly. The CWMOVE command is an Engineering Command anyway, so should not involve the TCS.

Section 3.3.8. MCS_Interpolation. What constitutes a slew in the MCS?

> **C** - The telescope will be defined to be slewing, by the MCS, during the time it takes to reach the first position specified with a new "track-id". The "track-id" is one of the data elements, along with demand azimuth, demand elevation, apply time and time sent which is received from the TCS at 20 Hz.

Section 3.3.10. MCS_Tape_Download. Compensation should be switched off during a slew if the download of Heydemann parameters is stopped.

> ▼ - Agreed.

Section 3.3.17. MCS_MainServos_Interface. (Requirement 00010) Azimuth range is incorrectly stated, it should be -180° to 360°. Elevation range should be specified as 15° to 90°.

> ▼ - Agreed.

Section 3.3.17. MCS_MainServos_Interface. Requirements 00040 and 00140 appear to be the same.

> ▼ - Agreed, one of these requirements shall be deleted.

Section 4.4.2. The MCS Event List. Additional event - elevation striker bracket changes position.

> ▼ - Agreed.

Section 4.4.2.5. Master Time Signal Lost. For stars near zenith transit a time error will introduce a Cassegrain rotation error which, for single off-axis guiding, will cause the science object to be pulled off by the magnitude of the error.

> **C** - If the master time signal is lost, the Bancomm oscillators in the TCS and MCS will slowly drift apart. The time taken to cause a drift which is unacceptable for tracking has not been determined. Loss of the master time signal will cause the "health" of the MCS to change to BAD. For single off-axis guiding, the magnitude of the error will also depend on the distance between the science object and the guide star.

Section 4.4.6. Figure 4-5 Data Flow Diagram for the Module MCS_Initialisation_Data. Will the apparent shift of the fiducials after the re-calibration of the Heidenhain tape be significant enough to demand a re-assessment of the fiducial positions?

> **C** - We do not believe so. The Heidenhain corrections are sub-micron (because of temperature variations, the repeatability of the fiducial switches is expected to be around the micron level) and only apply within pitches, the pitch count number is not affected by the compensation.

Section 5.4.1. MCS_MainServos_Interface. Each Motor and Co-ordinate System reports two 24-bit status registers for a total of 48 bits each. In addition, Binary-Ins will be needed to isolate individual bits from these words, for example the motor “In Position” or the “Home Completed” status bit.

> **C** - Yes, this is true. We will be using 2 Status records for the motor words, together with 48 Binary-In records to isolate the bits. Similarly, we will use 2 Status records and 48 Binary-Ins for the co-ordinate system words.

Section 5.5. Text ‘IRIG-B signals allow the cards in each crate to synchronise their clocks with one another to an accuracy of 100ns’. This might be claimed by Bancomm and measured in a nice and (electrically) clean lab, but is not achievable in practice. IRIG-B has a 1kHz analogue carrier. Due to phase noise introduced by interference, the receiver will have a jitter of (at the very best) 10 microseconds. I suppose that this is still sufficient for telescope tracking, but is nevertheless a factor 100 worse than the 100ns that is written.

> ▼ - Agreed. We believe the 100ns statement to be incorrect and will be removed from the document.

Section 5.5. Is information about leap seconds relevant? Surely what's relevant is that all access to time will be through timeLib and there are no leap seconds.

> **C** - This information is provided for the interest of the reader. When it was first written, the time library material was not so well developed.

Section 6.1. Initialisation of the MCS Software on Reboot. Is any distinction made between PMAC hardware reset and an IOC reboot. A software IOC “reboot” does not initiate a PMAC hardware reset. PMAC will continue to run autonomously and it will maintain encoder positions while the IOC reboots. Do you plan to utilise this operation or distinguish this from a reboot which includes a PMAC hardware reset? Somewhat related is the inverse scenario of a PMAC hardware reset without an IOC reboot. Do you have plans to support this event?

> **C** - The section on “rebooting” in the SDD needs expanding to cover these cases: If the “mv167” is rebooted, the MCS software, as part of its initialisation, will send the “reset” command to PMAC in order to put it in a known state with known settings for the I-variables etc. We only plan to allow PMAC to be reset via a software command from the MCS software or from a PC running the PMAC Executive. In the latter case, care will need to be taken since the PMAC driver and Executive are mutually exclusive, unless the ASCII part of the PMAC driver is disabled before using the Executive.
>
> ▼ - Expand “rebooting” section of SDD.

Section 6.1.3. Phase 3. What does last phrase ‘a particular EPICS record...’ mean?

> **C** - ‘a particular EPICS record...’ is referring to a record which will exist in the MCS database whose purpose will be to allow a sequence program to monitor it for processing. The record will be processed when an engineer presses a button on one of the mount Engineering Screens. This signals the end of testing that will have been carried out because the database failed to initialise correctly on a previous attempt. When the button is pressed, the sequence program changes state

from “TEST” to “INITIALISING” and the initialisation of the software and hardware begins again.

Section 6.2.3. Is it strictly true that DATUM is now an OCS sequence command?

C - Our interpretation at the last PSM was that DATUM would be a sequence command. Obviously, we realise that nothing has appeared in print yet!

Section 6.2.3. Is it safe to not perform a datum before moving the mount in engineering mode? If the mount was near a limit it couldn’t implement the velocity limiting specified in 3.3.3.3.1 of the system design since it wouldn’t know the distance to the limit.

▼ - A good point. I think we should always insist that the DATUM command is received before allowing the telescope to move whichever mode we are in.

Section 6.2.3. Datum. Presumably the Datum command will include the Cassegrain Rotator. What is the expected jitter from the fiducials? Does it matter how close to an edge the detector is when starting to move or is it best to pick up the next positive edge when starting from a position which is over a target?

C - The Cassegrain Rotator Control System (CRCS) will receive its own Datum command. The repeatability of the fiducials is expected to be about one micron. As stated in the document, the software will detect whether the sensor is currently positioned over a fiducial and will change the set-up of the capture procedure accordingly.

Section 6.2.3. ‘The positions will be stored in units of 5 milli-arcseconds.’. I assume that this is overkill, the repeatability of fiducial encoder will be MUCH more that this 5 milli-arcsecond.

C - Agreed. They are stored in units of 5 milli-arcseconds because this is the resolution of the virtual encoder.

Section 6.2.4. Setting TPRO won’t tell you which records are in the same lockset only which records are processed as a result of triggering the record that has TPRO set. For example if you consider the case of the apply and CAD records, records downstream of the CAD will often be part of the same lockset but they will only process if the CAD does.

C - This is correct. Setting TPRO tells you which records processed as a result of the record, which has TPRO set, processing. These records may or may not be in the same lockset.

▼ - The SDD will be suitably amended.

Section 6.2.6. Stop. Presumably it will include the Cassegrain Rotator.

C - The Cassegrain Rotator Control System (CRCS) will receive its own Stop command.

Section 6.2.8. Follow. For information how is this implemented? Is there any non EPICS VxWorks process? What is latency/jitter between time being read from the time bus and data sent to PMAC?

C - The implementation is described down to the level of an EPICS database, illustrated as a Capfast schematic in Appendix B. How the schematic processes is described in great detail in section 6.2.8. The algorithm running in the interpolating ‘genSub’ record is given in section 6.2.8.1. There are no VxWorks processes involved.

The time taken to read the time and then load the PMAC Move Argument Buffer will need to be determined. In the implementation described here, we are allowing 4 ms to: read the clock, perform the interpolation and download the data to PMAC. See section 6.2.8.4.

Section 6.2.8. Follow. The axis servo must provide proper ‘intercept’ of a new target at any time. The telescope can have any dynamics between its maximums and the new object has dynamics which are given by the object trajectory in the sky. The servo must therefore be able to cope with this situation and provide also a ‘smooth landing’ on a (what can be) a MOVING target. It is not clear from the description if the PMAC functions provide this. Our experience is that ‘motion controllers’ in general have to be carefully checked if they provide proper intercept and also proper tracking from the servo algorithm point of view. I suggest to make a test with a lab motor/tacho/encoder.

> **C** - We will be testing our implementation of the FOLLOW command. We believe the scheme as described will work. It will allow a ‘smooth landing’ on a moving target. It is unfortunate that we have to use a combination of PMAC ‘Jog’ commands and the application of a ‘Motion Program’. The alternative would be to calculate the total trajectory to a new source in the MCS database, but this would only be repeating what PMAC can do for us with the ‘Jog’ command - see Appendix A.

Section 6.2.8.1. Rather than static variables, EPICS records should generally be used for control data.

> **C** - Yes, we realise that this is the Gemini philosophy.

Section 6.2.8.3. ‘...maximum acceleration, a, is 0.1 $°/s^2$.’ If the acceleration is so low w.r.t the max. speed, it takes ‘ages’ to reach max. speed. Are the numbers mentioned the max. values during tracking? If yes, then the analysis is useless.

> **C** - We believe that the analysis as presented is correct. The values given are the maximum values for the axes, whether tracking or slewing. This paragraph is simply saying that the velocity of each axis will be restricted as we approach the ends-of-travel, insuring that we stop at the GIS limit.

Section 6.2.8.4. I really do support this principle of ‘scheduling’ all these real-time activities during the sample interval. It requires however that <u>all</u> activities are scheduled with one and the same clock, otherwise the clocks will run with different speeds and there will be a ‘bottle neck’ in the processing.

> **C** - Agreed. Following of the PMAC Move Argument Buffer will be synchronised to the Bancomm card via a 1 MHz output from the Bancomm.

Section 6.2.11. Log. It is important that data from Az, EL *and* Cass rotator are all available in consistent and related logs.

> **C** - All logs will be time stamped with universal time, as long as this is done in the CRCS as well, then the logs can be cross referenced off-line. We appreciate that this process must be made easy to use - or no one will use it!

Section 6.2.11. Log. Continuous high speed data logging is not a requirement. The Data LAN is not available to the MCS and the Control LAN must not be overloaded. Local buffering in memory or disk should be used as appropriate. What is the actual requirement?

> **C** - The requirement is that we should be able to log data sufficiently as to determine the cause of any problems. Therefore, the type of problem will determine how long we must log data for. This could be seconds or days. We simply point out that, if we were doing the best we can, in terms of PMAC’s abilities then we could put 1152 Kbytes/second over the LAN. Obviously, this can be restricted, by only logging every nth servo cycle. The question really is, how much bandwidth can the MCS have, when other systems are logging data at the same time? Does anyone have a global view for the Gemini Control System?
>
> Note that buffering does not solve the problem, if the logging is continuous. Also, if we wanted to detect a value that changed every servo cycle, then we could not sample every nth servo cycle. If the feature we are trying to detect is transient, we will not know how long we have to log data for in order to find it.

> **John Wilkes and Andy Foster (28)** - Need to define the whole method of data logging within the MCS as soon as possible. Including user friendly set-up and data retrieval, the maximum rate at which data can be transferred across the control LAN, whether a local hard disk will be required and whether triggered logging is possible and required.

Section 6.2.11. LOG. Support for PMAC Data Gathering is currently under design and development. My initial estimates of maximum data collection rates are slightly higher than 288 kb/s due to handling 24-bit PMAC words in 32-bit IOC integers. At this time I plan to use Channel Access for data transfer to a host computer. This imposes limits to the data transfer buffer size. The IOC memory buffer will likely be smaller while the transfer task repetition rate will be higher.

> **C** - We are hoping to make use of Tom’s implementation of data gathering for PMAC. This could potentially save a good deal of work. I have had E-mail discussions with Tom over the design details of the logging functionality.

Section 6.2.12. Tolerance. How does MCS know where commands arrives from? Arguments should be treated in the same way regardless of where command originates.

> **C** - The MCS will not know, unless an extra parameter is sent with each command, saying where the command came from. We do not intend to do this.

Section 6.2.13. I don't think the TCS should be reading records in the MCS and then making a decision about which commands to send. If the MCS finds itself in the position given in the example would it not be better to include the wrapinit functionality as part of the datum command to the axis.

> ▼ - Yes, this could be done. I hadn't appreciated that the TCS would not want to read records in the MCS database, when the MCS comes on-line. If WRAPINIT functionality is put in the DATUM command, then WRAPINIT can be removed from the list.

Section 6.2.16. DRIFT. An alternative to using the jog command, have you considered using a motion program containing the “F” (feedrate) command? An advantage would be having no change made to the jog velocity. This may assist in assuring the original jog velocity is set should the DRIFT execution be aborted for some reason. For calibration or tuning exercises you may find it more flexible to be executing a motion program rather than a jog.

> **C** - We did think about doing this. However, we opted for the “jog” command because we wanted to be able to distinguish between motion caused by a “jog” and motion caused by a “motion program”. “jogging” in PMAC terms will indicate a slew in telescope control language. The “drift” command is a special kind of “slew”.

Section 6.4 MCS and SAD. Is it more efficient to have a 1 Hz scan (pull) than to write changes directly (push) ?

> **C** - In terms of MCS efficiency it is more efficient to have the SAD pull the values across. There is no good reason for pushing.

Section 6.5. The MCS Engineering Screens. The PC PMAC Executive cannot be run concurrently with EPICS PMAC support due to fundamental constraints in communicating with PMAC. However, my experience has shown that by augmenting the application database and screens with a Tcl/Tk application, one can approach the functionality of the Executive. In some respects the on-line environment is even nicer than that of the PC, particularly when handling more than one PMAC (I have 21 PMACs installed across eight crates). As you point out, download and upload capability is needed as well. I will be adding this feature.

C - One of our goals is to implement a PMAC Executive type interface using "dm" and Tcl/Tk. Any Tcl/Tk interfaces which Tom has already built would be very useful to us and would, again, save on repeated work.

Section 7.1. The analysis is only valid for certain begin and end conditions. It should also work with telescope at any speed and acceleration, in addition to the new target at any speed & acceleration.

C - This is a description of how the PMAC calculates the trajectory during a Jog which by definition starts and ends with the axis being stationary. For tracking, a PMAC motion program will be used in conjunction with the Jog command.

Section 7.1. The algorithm takes into account Vmax and Amax in order to go from a to b. There is however the problem that the acceleration cannot instantaneously change due to limitations in the amplifier/motor (the so-called Full Power Bandwidth or Slew Rate). Also, the sudden change of torque (T = inertia × acceleration) could easily 'kick' the fragile optics and will certainly excite Eigenmodes.

I also think that the fast wear of the friction wheel can be due to this. I therefore recommend to limit the 'rate of change' of the acceleration. The required extra time for a pointing is negligible when the parameters are properly selected.

C - Controlling jerk (rate of change of acceleration) is not simple when using PMAC's jog command. We hope that the limit imposed by the amplifier/motor will be sufficient to prevent exciting resonances and causing unnecessary wear of the drive roller. If this proves not to be the case, we can try lowering the amplifier bandwidth. If it turns out that we really do need control of jerk from the demanded trajectory then we will have to go away from using the jog command and use the move argument buffer for slewing as well as tracking.

2.4 Comments on PTP

Section 1.3. What is meant by the last paragraph.

C - According the IEEE standard, the test plan contains details about schedules and resources needed to carry out testing. This information is included as part of the MCS project plan and it seems pointless to repeat it here.

Section 2. Reliability tests should be included. These should be based upon TCL/TK scripts with many repetitive tasks.

▼ - Relevant tests will be added.

Section 2.3.2. VME enclosure power supply is ±12V not ±15V.

▼ - Document will be amended.

2.5 Comments on PMAC Set Up Documents (MCSJDW14 & MCSJDW16)

MCSJDW14. General Purpose I Variables. For completeness, there are other I variables used as well by the EPICS PMAC driver. For example, I55=1, which enables the DPRAM Background Variable Buffer. The full list of I Variables which effect the operation of the EPICS support will be documented in my EPICS PMAC Support Reference, being written.

C - All I variables that do not remain as default will be detailed in these documents as they are identified. In the case of I55 (and the other DPRAM control variables, i.e. I19, I48, I49 and I59), upon PMAC re-boot the variable will be as default (i.e. 0). The MCS software, as part of its initialisation, will set up the DPRAM buffers as required. MCSJDW14 is meant to document the default set up of the PMAC cards.

MCSJDW14. Motor Channel 2 - Axis Servo Algorithm I-Variables. How have the software position limits been derived from the hardware limits? The TCS is assuming limits in the range 15° to 90° and -180° to +360° for the software limits and these should agree with any limits in the MCS. Does the limit of 89.5 for example prevent access to the zenith when in engineering mode.

▼ - These values need to be changed to reflect the new damper position (initial contact at 90.4°). The following describes the way the PMAC limits are calculated: The required observation limit is 89.5° (ICD-G0005). However, for zenith parking, we need to computer control the axis up to 90°. The damper first contact position is 90.4° (ICD-G0004). The GIS limit has to be 90.05° to allow the brakes to stop the telescope at full velocity before the damper is reached. If the dynamic velocity limit (DVL) method is used, the MCS limit (i.e. position of zero maximum velocity) can in theory be made the same as the GIS limit. However, I suggest that it is placed just inside the GIS limit so that an overshoot in the servo can't trigger the GIS limit, say 90.02°. We now have to choose where the PMAC limit goes. I suggest making it the same as MCS DVL limit, 90.02°, or switching them off altogether and relying on EPICS to enforce the MCS limit.

Summarising these results together with a similar argument for the horizon end and azimuth, we get:

	Zenith	Horizon (Obs.)	Horizon (Man.)	Az. -ve	Az. +ve
Observation Limit	90	15	-	-180	360
MCS DVL zero	90.02	14.9	2.73	-182	362
PMAC Limit	90.02	14.9	2.73	-182	362
GIS Limit Switch	90.05	14.85	2.68	-184	364
Damper Start Position	90.4	14.5	2.33	-185	365
Fully Compressed Damper	92.73	12.17	0	-188.25	367.67

▼ - Add a drawing to the CSDD to show graphically the position of these limits.

MCSJDW14. Motor Channel 2 - Axis Servo Algorithm I-Variables. As there are no hardware filters to provide limiting bandwidth protection a rationale needs to be developed to prevent the application of gain at structural resonant frequencies which would result in under-damped oscillation of the structure. During tuning of the servo algorithm or setting up of parameters on initialisation how does one prevent the possibility of a mistake occurring? Can simulations be carried out using the dSPACE system to assess the danger involved?

C - There are digital filters within the power amplifiers. These are only programmable via the serial port and it will not be a simple matter to do this since in normal operation there will be no connection to the serial port. One would have to open up a drive cabinet and physically connect a terminal or PC to the amplifiers - not something done by accident.

As far as PMAC is concerned, in the current scheme of things it will be very difficult to stop bogus servo parameters from being set. One could imagine a set of protected I variables that the software would make read only in operational modes. This doesn't protect against mistakes in tuning or tampering via the PMAC executive, but gives a level of protection against tampering via the engineering screens.

Andy Foster (29) - Look into this 'read only' mode for certain PMAC I variables.

John Wilkes (30) - Run some unstable PMAC configurations on the hardware simulator to assess the dangers involved.

Connector J2 - JPAN 26-way IDC Header. You might consider using connector pins F2LD/ and INIT/. The F2LD/ signal can provide an external equipment monitoring system an indication of PMAC health. If a PMAC Watchdog fault occurs then alarms can be triggered or actions can be taken. For example, should brakes be applied? The INIT/ signal can reset the PMAC hardware. We have wired INIT/ to a local push-button to provide a PMAC reset independent from an VMEbus reset.

> **C** - We currently see no requirement to have a separate hardware reset for PMAC. Note that PMAC can be reset with the $$$ command. We will bear these suggestions in mind should the need arise.

2.6 Comments On Circuit Diagrams

General comment. Be very careful when you accept an external signal. For example in the tacho averaging circuit, one can see that there are differential amplifiers with 4 resistor to feed the external tacho signals into the velocity controller electronics. These 'differential amplifiers' do very likely not provide the common mode rejection that you are looking for. Better use 'instrumentation amplifiers', which are a bit more expensive, but they are intended for this function and provide much better CMRR. Also, allow the possibility to use RC filtering for all analogue input signals.

> **John Wilkes (31)** - Look at using instrumentation amplifiers instead of standard op-amps. Note that there is an RC filter included in the summing amplifier.

Velocity Combiner. Is the auxiliary circuit is for testing and moving the telescope from a voltage source? If there are any lengths of cable connected to the aux. and GIS inputs then we must be sure that they are sourced at low impedance, shorted out or whatever when the PMAC channel is in use. How come the PMAC channel is switched and the others aren't?

> **C** - The auxiliary input is for test purposes, specifically frequency response tests. The switch is intended to break the position loop so an open loop frequency response can be conducted, at this stage it is not known whether this feature is really needed. A prototype of this circuit and the tacho averaging circuit will be tested during the factory tests.
>
> ▼ - A link will be included in the circuit to zero the auxiliary input into the velocity command combining circuit.

Monitoring Circuits. A/D converter. There is no self checking of the A/D reference (by reading in a separately sourced voltage etc.) has this been considered?

> **C** - It was considered, but was dropped because of very tight space requirements plus the need to give one of the analogue inputs a 'dual function' – that of reading a voltage source and reading a normal input. The trade-off was not felt to be worthwhile.

Monitoring Circuits. Binary Inputs. The opto-isolated inputs are not adequately balanced for fast switching. This would be a problem if they are used for counting pulses or operating on edge trigger systems. I don't think this is an issue with what is presented here as 'contact bounce' and the like are dealt with in software but it may be a restriction on future use.

> **C** - I don't understand what is meant by 'adequately balanced'? If some form of LED driver circuit is required to improve the switching performance of the opto-isolator, then it should be the responsibility of the user to provide it. In general, the simple arrangement given will prove sufficient.

2.7 Comments on Servo Specification Document (MCSJDW10)

The analysis of the systematic servo error as shown in the document is important. However, the servo will mainly suffer from two disturbances which are not mentioned: wind and friction. The analytical error as mentioned in the document will be 'peanuts' compared with the effect of these two 'fun killers'.

> **C** - Friction is included in the non-linear model that was used in determining the 'Telescope Errors'.

Wind is a bit of a worry, especially with Gemini given the unorthodox dome design. Wind will act as a disturbance to the servo system, but it is very difficult to quantify the frequency spectrum of this. Low frequency disturbances (< 1 Hz) will be rejected by the drive servo. For the rejection of higher frequency disturbances, we rely on the tip/tilt secondary mirror. I am sure that there are many more ‘fun killers’ that we have not come across yet and we will try to add them to the simulations as we find them.

John Wilkes (32) - Examine the effect of disturbances (including wind) using the hardware simulator.

2.8 Comments on Tape Encoding System Requirements Specification (MCSJDW12)

General comment. Having the tape encoder as a REPEATABLE system with SUFFICIENT resolution, it is justified to eliminate the friction coupled encoder and maybe also the fiducial encoder. The friction coupled encoder will not tell you more than the tape encoder tells you already. The tape encoder might need a separate identification of its reference marks, but this identification does not have high requirements on repeatability in this case.

C - It is true that in general operation the friction driven encoder will probably not be used. However, it is still planned to install the FDE. It will be used extensively during commissioning (exclusively during the factory tests as the tape encoder will not be available) and as a backup system as it does not depend on complex interfacing and interpolation methods. See earlier in this report (Comments on CSDD, Section 3.2.3.3.2.1) for a discussion on the elimination of the fiducial switches.

Section 2. Two tapes for elevation axis. I do not know the arguments, but there is considerable saving in cost possible by using only one tape. If the elevation axis is driven with an equal torque from both sides, the ‘twist’ in the centre piece will not be measurable. Example: also the NTT works happily with an encoder on one side only.

C - It was always intended to buy two tapes for elevation. The cost saving is not as significant as it might seem because of the lengths of tape involved. It also allows for more heads to be mounted, as there is a space restriction on elevation. The virtual encoder allows one side to be switched off if there is a problem with trying to read both sides simultaneously.

Section 3.1.3. The mounting of the heads and maintaining the required tolerance for the air gap is not obvious: check this carefully with the mechanical engineers.

John Wilkes and Mark Warner (33) - Find out the variation in air gap over the entire rotation of the tape. Use the tape encoder test rig to determine the effect of this variation.

Section 3.2. Requirement 0200. I can only recommend to fix firm requirements for the EMC (i.e. immunity and emission) for the whole project. Too often, equipment suppliers leave this ‘burden’ to the system integrators. Moreover, the EEC directive on EMC gives the force that suppliers of industrial equipment respect international norms on EMC. The user has however to set the ‘compatibility levels’.

For the VLT, we have chosen ‘light industry’ which implies that work has to be done on both sides: emission (e.g. of heavy duty motor variable frequency inverters) and immunity (e.g. CCD detectors). Target is to avoid problems during system integration which can then only be solved with expensive re-design.

C - Agreed. We had trouble trying to find out what the Gemini standard on EMC was. We were also tendering to both European and non-European companies for the tape encoding system, so we had to be very vague in the tender document and simply asked companies to state what standards their equipment met. We were satisfied with Heidenhains reply, which was:

The Heidenhain equipment fulfils the requirement for electromagnetic compatibility according to 89/336/EWG, when properly installed. Compliance with the regulations of the EMC guidelines is based on performance to the following standards:

- DIN EN 50 082-2 Electromagnetic Compatibility - Generic Immunity Standard specifically:
  Electrostatic discharge on housing parts - EN 61 000-4-2 severity level 4
  Burst on conducting lines - EN 61 00-4-4 severity level 4
- DIN EN 50 081-1 Electromagnetic Compatibility - Generic Emission Standard

2.9 Comments On ICD’s

ICD 1.1.12. Section 4. File names mentioned should be in the standard Gemini title case.

▼ - Change file names to standard Gemini title case.

ICD 1.1.8/1.1.12. Title Should be “Alt. Cable Wraps to Mount Control ICD”.

▼ - Agreed.

ICD 1.1.11/1.1.12. This ICD is out of date.

Andy Foster (34) - Bring TCS/MCS ICD up to date.

ICD 1.1.12/1.1.13. Need to change the order of removing brakes and enabling amplifiers.

▼ - Agreed. See comment under CSDD, Section 3.3.3.2.

ICD 1.1.12/1.2.10. This ICD needs to be updated.

Andy Foster & John Maclean (35) - Bring MCS/PCS ICD up to date.